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Durable Purchases over the Later Life Cycle*

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Abstract

We investigate life-cycle patterns of demand for services from household durables using UK panel data. We take careful account of prices, demographics, labour supply and health. Demand for consumer electronics rises with age, while the demand for household appliances is flat. These findings contrast with the well documented decline in non-durable consumption at older ages, and suggest that studies that estimate the overall discount rate from nondurable consumption may underestimate consumer patience and the savings required to fund retirement. We also find important non-separabilities between the demand for durables, labour supply and health status.

I. Introduction

There is a large empirical literature which documents life-cycle patterns of household consumption or expenditure, particularly as households move into later life. It has been almost entirely concerned with life-cycle patterns of *non-durable* consumption while life-cycle patterns of durable, non-housing consumption have been little studied. In this paper, we address this important gap in the literature.

Life-cycle patterns of consumption are of interest for a number of reasons. First, the life-cycle model developed by Modigliani, and its many modern descendants, form the basis for much economic analysis, in public finance, macroeconomics and other areas. This class of models suggests that households should pursue smooth consumption paths. Thus, a failure to smooth consumption between, for example, working life and retirement, would represent a key challenge to the life-cycle framework. Second, falls in consumption in later life represent not just a challenge to an important economic model, but potentially significant

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welfare losses. If the combination of current public policies and private preparations do not allow households to maintain an appropriate standard of living in retirement, this is a matter of considerable policy concern. Finally, as populations throughout the developed world are rapidly ageing, forecasting future demand patterns necessarily requires an understanding of age effects on both the level of total spending and the allocation of that spending across different goods and services.

The literature on *non-durable* consumption documents a drop in later life, and particularly at retirement entry (see, e.g., Miniaci, Monfardini and Weber, 2003; Smith, 2006; Battistin *et al.*, 2009; Lührmann, 2010). The general decline in non-durable consumption in later life is sometimes attributed to consumer impatience (Gourinchas and Parker, 2002), while the sharper drop at retirement has been explained by increased home production and the cessation of work-related expenses (Banks, Blundell and Tanner, 1998; Aguiar and Hurst, 2005). There is also a well-developed literature on life-cycle patterns of housing arrangements, and in particular, the degree of 'downsizing' in later life (see, e.g., Banks *et al.*, 2010; Chiuri and Jappelli, 2010). Housing is a very important durable, but it is also unusual in a number of respects, most notably because it combines features of a consumption good with those of an asset.

In contrast to the literatures on non-durable consumption and housing, life-cycle patterns of durable, non-housing consumption have been little studied. Durable, non-housing consumption is an important component of total household expenditure. Durables and semi-durables (including clothing) account on average for about 25% of total non-housing consumer spending of those above age 40.[1] Expenditures on non-housing durables have been shown to behave quite differently from non-durable expenditures at higher frequencies; see Browning and Crossley (2009). At life-cycle frequencies, the presence of a 'pure' age effect for durables would entail revision of calculations on how much households should be saving for retirement, and a reassessment of studies of non-durable consumption. For example, if in later life, the taste for durables is declining at a faster rate than for non-durable goods, then households will not need to save as much for retirement as would be implied by the time path of non-durables demands and the assumption that relative preferences for different categories of goods are constant. On the other hand, if tastes for durables decline more slowly (or even rise) with age, retirement needs must be revised upwards. Moreover, in this case, less consumer impatience is necessary to reconcile the data with the life-cycle model, and studies based on non-durable expenditure will only have overestimated the overall discount rate (because they attribute a decline in non-durable spending to overall impatience, rather than to a relative preference for durables that increases with age). Thus the lack of studies of the pattern of durable, non-housing expenditure at life-cycle frequencies is an important gap in the literature.

We employ longitudinal data on households' spending on durable goods from the British Household Panel Study (BHPS) between 1997 and 2008 to study life-cycle patterns of durables demands. We focus on two specific categories of durables for which we have good data: white goods or appliances (freezers, microwaves, dishwashers, washing machines and tumble dryers), and consumer electronics (personal computers, CD players, TVs, VCRs, phones, cable TV and satellite dishes). For the reasons just outlined, we shall

[1] Authors' own calculations based on the UK Expenditure and Food Survey.

be particularly concerned with identifying pure age effects in the demand for these durables. As we shall see, the raw data suggest strong negative age effects. However, these could be due to a combination of three factors: pure age effects; age-related changes in household composition, labour force status, or health conditions; or cohort effects.[2]

A complementary goal of the paper is to document how demands for these goods depend on household composition, labour force status and health status. In particular, non-separabilities between commodity demands and health are critical to a range of economic and policy questions, such as the optimal provision of health or disability insurance, but there is very little prior empirical evidence on how demand varies with health status (Lillard and Weiss, 1997; Finkelstein, Luttmer and Notowigido, 2009). The importance of non-separabilities between leisure and demands has been emphasized by Browning and Meghir (1991).

The analysis reported in this paper is most closely related to work by Aguiar and Hurst (2013), Alessie and De Ree (2009) and Fernandez-Villaverde and Krueger (2007). Aguiar and Hurst investigate the hump-shaped life-cycle profile of *non-durable* expenditures in detail by breaking down non-durable expenditures into several sub-components. Our analysis is complementary to theirs, in that we also focus on particular subcomponents of expenditure, but we focus on durables rather than non-durables. Fernandez-Villaverde and Krueger (2007) investigate durable and non-durable consumption over the life-cycle using the US Consumer Expenditure Survey between 1980 and 1998. Durable expenditures are defined in a comprehensive way, including expenditures on owned and rented dwelling, appliances and furniture, vehicles, books and electronic equipment. Hence, their durables category is dominated by housing and cars. Alessie and De Ree (2009) report a similar exercise with Dutch data. Both Alessie and De Ree (2009) and Fernandez-Villaverde and Krueger (2007) report that expenditure on a very broad aggregate of durables declines in later life.

Our analysis goes beyond their work in a number of important respects. First, we model demand for services from particular durable goods rather than expenditure on a broad aggregate of goods. Aguiar and Hurst (2013) find that sub-components of non-durable goods display significant differences in their life-cycle patterns. We posit that the differences may be even more important for durables. The age patterns of medium-sized durables may be quite different from those of housing and even cars because of large differences in durability, scope to be used as collateral and resale possibilities. Even amongst medium-sized durables, life-style changes with age may have very heterogeneous effects on the demands for the services provided by different goods. For example, some household appliances may be substitutes for non-market time while consumer electronics may be complements to leisure time. Modelling a large expenditure aggregate will miss these important differences.

Second, we employ rich British panel data which, to the best of our knowledge, have not been used for this purpose previously.

[2] Of course, being less healthy, doing less market work and having one's children leave home are all part of what we broadly understand as ageing. These things are all potentially observable and so can be conditioned on when we model demands for durables or other goods. By 'pure age effects' we mean those changes that happen over time above and beyond these observable aspects and, in particular, gradual shifts in preferences. To the extent that our empirical measures of, for example, health are imperfect, our empirical analysis will necessarily conflate changes in preferences with subtler changes in health.

Third, we provide a deeper and more flexible modelling of demographic effects. Alessie and De Ree (2009) and Fernandez-Villaverde and Krueger (2007) adjust expenditures by a standard equivalence scale; the latter study also explores the sensitivity of their results to alternative equivalence scales. Browning and Ejrnæs (2009) show that detailed modelling of household composition significantly alters the life-cycle pattern of non-durable consumption. Moreover, Alessie and De Ree (2009) and Fernandez-Villaverde and Krueger (2007) employ the same equivalence scale for all categories of expenditure (total, non-durables, and durables). This rules out the very likely possibility that different categories of goods and services have different degrees of publicness (food is essentially private, but consumption of services from cars and televisions is much less rivalrous.)

Fourth, as noted above, we account for the demand effects of changing health conditions and labour supply over the life-cycle.

Finally, and importantly, we depart from all three papers just cited on the related issues of price and time effects. All three move beyond the single (non-durable) consumption composite of the previous literature, and consider multiple categories of goods. However, none of these papers pay attention to the potential role of relative prices. For example, Fernandez-Villaverde and Krueger deflate durable and non-durable expenditures by specific price indices to give real purchases (quantities), but do not allow for further effects of prices on quantities. In contrast to the previous analyses just cited, we allow for price responses explicitly in our modelling. These are particularly important in the face of drastic declines in the prices of appliances and consumer electronics since the 1980s (Berndt and Rappaport, 2001). In a model of frictionless durables adjustment, the relevant price of a durable is the user cost. In such a model, durables purchases in later life are driven by changes in the desired stock and by replacement (because of depreciation). The quantity required to replace depreciation will depend on the desired stock and hence on user cost; changes in user costs will be one driver of changes in the desired stock. We construct, present and employ user cost series for electronics and for appliances, for the United Kingdom, for the period covered by our data. There is considerable variation in user costs over our sample period.

The issue of price responses (for durables, user cost responses) is related to the issue of disentangling age profiles from cohort and period effects. To a first approximation, user costs are common to households of different ages and birth cohorts at a given point in time.[3] Thus, if price and user costs responses are not explicitly modelled then they should be thought of as a component of more general time-effects. Aguiar and Hurst (2013) assume away time effects (effectively restricting them all to zero). Thus, they do not account for variation in user costs, explicitly or implicitly. Alessie and De Ree (2009) and Fernandez-Villaverde and Krueger (2007) identify age effects by imposing the widely-used restrictions suggested by Deaton and Paxson (1994); that is, they restrict time effects to be mean zero and orthogonal to a time trend. If user costs (and changes in user costs) are an important component of time effects, and if those variables are trended, this restriction is inappropriate. With estimates of user costs in hand we can investigate this issue empirically.

[3] User costs might vary with age at a point in time if, for example, households of different ages faced different interest rates. We will not pursue this possibility in this study.

A preview of our findings is as follows. First, we find strong evidence of a time trend in the user costs for both appliances and electronics. The presence of a trend in user costs suggests that the Deaton and Paxson (1994) procedure is not appropriate and motivates our use of an alternative approach which accounts for time effects by explicitly modelling user costs and changes in user costs. In our descriptive cross-sectional analysis, we find strongly decreasing expenditures for appliances and consumer electronics as household (heads) age. These declines are much larger for electronics than for appliances. However, when we estimate our model of demand, we find that the downward-sloping age-specific profile of appliances demand is entirely explained by cohort effects. Once we condition on these, there is no age effect. For electronics, conditioning on cohort reverses the cross-sectional pattern so that demand for electronics rises with age. We find no effect of user costs on the demand for appliances (suggesting that the demand for appliances is very price-inelastic). We find modest but statistically significant reductions in the demand for electronics with increases in the user cost. We find significant effects of household size and composition on the demand for both categories of durables. We find no impact of leisure or health status on the demand for appliances, but these variables have significant effects on the demand for consumer electronics. This highlights the importance of studying non-separabilities between leisure or health and consumption at the level of disaggregated demands. While demographics (and in the case of electronics, user costs, leisure and health status) are significant determinants of demand, they have little material effect on the age profile of demands. Once we condition out cohort effects, the age profiles are quite robust to other changes of specification.

In section II, we introduce the BHPS data which form the basis for our study. We also present cross-sectional age profiles of durable expenditure. The rest of the paper deals with understanding these patterns. Section III derives the reduced-form empirical framework from a model of frictionless durables adjustment. The section also contains our discussion of the identification of age, cohort and time effects, and presents estimates of user costs. Section IV presents and discusses estimated age profiles and other determinants of durables demands. Section V concludes.

II. Data and cross-section profiles

The British Household Panel Survey

The BHPS is an annual panel survey consisting of a nationally representative sample of households. It started in 1991 with about 5,500 households containing about 10,000 interviewed individuals from 250 areas of Great Britain. We also use the samples of 1,500 households in each of Scotland and Wales, added in 1999, and 2,000 households from Northern Ireland, added in 2001. The special advantages of the BHPS are its long time dimension and its broad scope. It covers a wide range of socio-demographic and economic characteristics such as household composition, living conditions, health status, labour market behaviour and other socio-economic characteristics.

While not a comprehensive expenditure survey like the British Living Costs and Food Survey, the BHPS does contain some questions on household expenditure. Apart from asking about monthly spending for food consumed inside and outside the household, monthly leisure expenses and expenses on fuel and heating, it also contains a battery of questions on ownership, usage, and expenditures on a set of 12 durable goods which we group into two categories. The first category is *household appliances*, comprising freezers, microwaves, dishwashers, washing machines and tumble dryers. The second group, *consumer electronics*, consists of personal computers, CD players, televisions, VCRs, phones, cable TV and satellite dishes. Expenditures on these 12 items are recorded from 1997 onwards, so we use the waves between 1997 and 2008. In each household, one respondent in the household is asked whether a specific durable item was bought in the last 12 months. If the answer is 'yes', there is a follow-up question on the amount spent for that durable. We aggregate this information across the five appliances and across the seven consumer electronics.

The long panel nature of the BHPS allows us to observe the consumer behaviour of households over a period of 12 years, to follow households over time and to distinguish between age and cohort effects in the acquisition and replacement of durables. Age and cohort are defined as in the BHPS, i.e., in terms of the age of the head of household. Due to our focus on the second half of life, we restrict the sample from 108,085 observations between 1997 and 2008 to 73,568 observations of households with a head above age 40. Out of those, we obtain 71,067 (71,071) observations for which durable expenditures for appliances (consumer electronics) are observed. Our panel is unbalanced for two reasons – (i) panel attrition over time, (ii) fresh-up samples are added in 1999 and 2001. However, more than 67% of households are observed over at least four of our twelve sample periods. Since our panel is unbalanced, lagged values (which will play an important role in our analysis) are not always observed for each household in each year. Thus, our ultimate sample includes ca. 60,700 observations or around 3,000–5,000 households per year.

Figure 1 presents information on the age profiles, beyond age forty, of annual quantities (or real expenditures) on appliances and electronics measured in £ sterling at 1997 prices. Note that the y-axis has a logarithmic scale, so that the Figure shows proportional changes with age in cross-section. For comparison, we also present the age profile of annual real (1997 £) expenditures on an important non-durable good: food (aggregated from food in

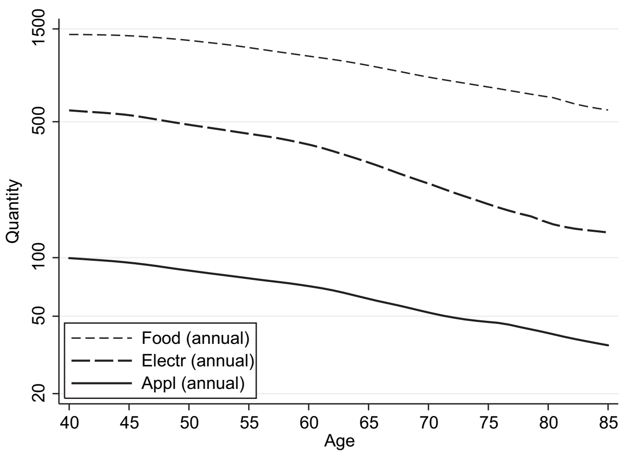

Figure 1. Durable Quantities by age (measured as real expenditures in 1997 £)

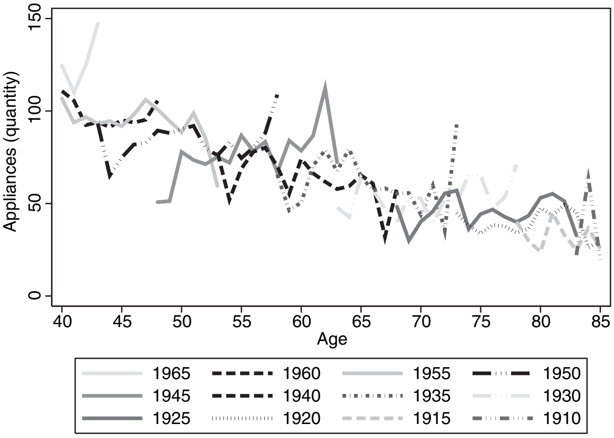

Figure 2. Age profiles, by cohort, of appliances quantities (measured in 1997 £)

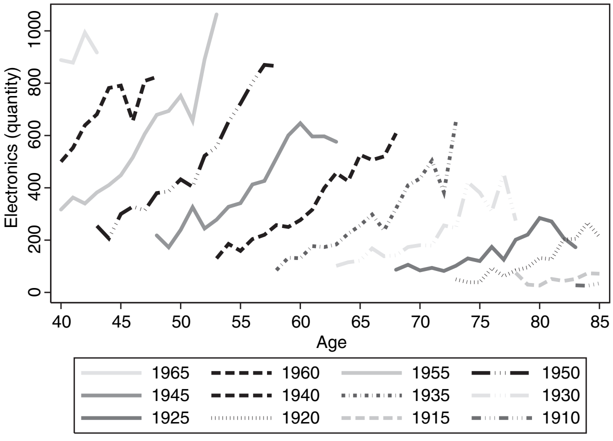

Figure 3. Age profiles, by cohort, of electronics quantities (measured in 1997 £)

and out of the household).[4] The profiles are based on pooled data from multiple years of the BHPS. Real expenditures on food, appliances and electronics appear to fall with age. The rate of proportional fall is similar for the three goods until the age group 60–65 years (which were the state retirement ages for women and men respectively, at the time the data were collected).[5] After 65 years of age, the proportional fall in real spending on electronics appears to accelerate. Note that equiproportional falls imply larger absolute declines in

[4]The BHPS records spending on food at home at the household-level and personal spending on food outside the home. We aggregate spending on eating out to the household-level and create a variable that captures overall spending on food consumed in and outside the home. Since food expenditures are asked in brackets in the BHPS, we adopt the coarse method of using midpoints of the brackets to generate a continuous measure of food expenditures.

[5]The state pension age (SPA) in the UK was 60 for women and 65 for men until 2010, and has increased gradually for women since to reach age 65 by 2018. The SPA is scheduled to be increased to 66 until 2026 (by one month every month), to 67 until 2036 and to 68 until 2046 for both genders. The state pension age is delinked from the retirement age (i.e. the age a person stops working). The compulsory retirement age of 65 years was abolished in 2006. Employment rates of older workers, especially women, have increased following these pension and employment reforms (See Banks and Smith, 2006).

spending on electronics and food. Importantly, these age profiles are a compound of cohort, time and pure age effects as well as changes due to changing prices, household composition and lifetime resources.

Figures 2 and 3 show cohort age profiles of spending on appliances and on electronics respectively. Figure 2 suggests that declining spending on appliances in Figure 1 is a genuine age effect. Figure 3 suggests that the declining spending on electronics with age in Figure 1 is an artefact of large cohort effects. In Figure 3, the demand for electronics appears, if anything, to rise with age. Nevertheless, this interpretation of Figures 2 and 3 does not account for time effects which may be particularly large in the case of consumer electronics (where prices have fallen substantially over time). We turn now to the identification of the relative strengths of age, cohort and time effects and, in particular, whether there are pure age effects.

III. Empirical specification

Identification and prices

We seek to separate pure age effects in the demand for durables from time and cohort effects. We also want to control for household-specific factors which are highly correlated with age, such as household composition. Thus, we wish to estimate an equation of the form:

$$d_{i,c,t} = f(z_{i,c,t}) + \gamma(a_{i,c,t}) + \phi(t) + \varphi(c_{i,c}) + e_{i,c,t}, \tag{1}$$

where $d_{i,c,t}$ is the quantity of a durable category purchased by household i in birth cohort c at time t; $f(z_{i,c,t})$ is a function of socio-demographics of the household (excluding age); $\gamma(a_{i,c,t})$ is a set of age effects, which describe the age profile, our object of interest; $\phi(t)$ and $\varphi(c_{i,c})$ are sets of, respectively, time and cohort effects; and $e_{i,c,t}$ is an error term with $E[e_{i,c,t}|z_{i,c,t}, \gamma(a_{i,c,t}), \phi(t), \varphi(c_{i,c})] = 0$. It is well known that because age $a = t - c$, the parameters of equation (1) are not identified (on either panel or repeated cross-section data).

The age patterns in Section II confound age, period and cohort factors. For example, one candidate explanation for the age profiles observed in Section II is the existence of cohort-specific tastes for durables. A second explanation may be the existence of period effects, for example, due to user cost or product changes.

In empirical studies of consumption and saving, the fundamental identification problem in equation (1) is often solved using an approach proposed by Deaton and Paxson (1994), which assumes that the time-effects are mean zero and orthogonal to a (linear) time trend. This approach is adopted by Fernandez-Villaverde and Krueger (2005, 2007) in their studies of life-cycle expenditures. Aguiar and Hurst (2013) respond to the fundamental age-cohort-time identification problem by setting all time effects to zero. If the true time-effects in the data contain a linear trend, either of these procedures will force that trend into both the estimated age and cohort effects, resulting in bias.

One period-specific factor that likely affects durables demand is cost, and so a useful starting point in considering potential period effects in durables demand is an examination of the relevant prices and costs. The durables considered in this paper, especially consumer electronics, experienced quality improvements over time as they are subject to technological progress and product innovations. Since 1996, for example, consumer electronics has seen the introduction of iPods, tablet computers and flat-screen TVs. The prices we use are taken from the Office of National Statistics retail price index time series on electrical appliances (DOCC) and audio-visual equipment (DOCZ). The Office of National Statistics calculates Laspeyres-type price indices, adjusting the basket of goods each period. Index movements are corrected for quality changes via hedonic regression (CIP Manual, 2007) so that the index captures pure price changes.

In a neoclassical durables model, the relevant price for the durables is not the purchase price but the discounted user cost (or rental price), v_t^*:

$$v_t^* = \frac{1}{\prod_{\tau=1}^{t-1}(1+r_\tau)}\left(v_t - \frac{(1-\delta)}{(1+r_t)}v_{t+1}\right) \tag{2}$$

where v_t is the (nominal) purchase price of durables at time t, δ is the (good-specific) depreciation rate and r_t is the (nominal) interest rate between t and $t+1$.[6] We calculated user costs according to equation (2) using depreciation rates from the Bureau of Economic Analysis Fixed Assets Accounts (BEA, 2004). These are 0.165 for appliances and 0.183 for consumer electronics. Nominal interest rates are annual average rates of discount for three-month Treasury bills from the Bank of England.

Figure 4 shows absolute prices, (log) user costs, and changes in (log) user costs for appliances and electronics over our sample period. Whilst food prices display the usual increasing pattern, the prices of durables display a very strong negative trend. In our sample period, prices for appliances fell by almost 40%, while the price level for consumer electronics fell to one quarter of its 1997 price level. User costs depend on depreciation and the interest rate as well as changes in prices; they also show a significant trend. As we shall develop below, while the stock of durables will depend on the user cost, durable purchases will depend both on the user cost and user cost changes. Changes in (log) user costs in turn reflect changes in the rate of price change. Formal statistical tests for linear trends in log user cost and its change over time confirm that there are time trends in the log user costs of electronics and appliances but not in the changes.[7]

In the light of these results, the two identification strategies mentioned above – the zero time effects assumption or the Deaton and Paxson approach – do not seem appropriate for our analysis. An alternative to placing statistical restrictions on the time (or age or cohort effects) is to model one or more of these effects with observable variables. For example, Kapteyn, Alessie and Lusardi (2005) show that cohort effects in the Dutch household net wealth data are well captured by variables measuring productivity growth and social security generosity. We will follow a similar approach. We now look to theory for guidance in developing the specification of equation (1). In the next section, we first consider the implications of a neoclassical model of demand, and then consider the consequences of irreversibility and other departures from the neoclassical framework.

[6] We could, of course, also work with the 'real' interest rate and 'real' prices but in a multiple goods context working with nominal prices and nominal interest rates avoids the potentially awkward choice of an appropriate deflator.

[7] Full results available on request.

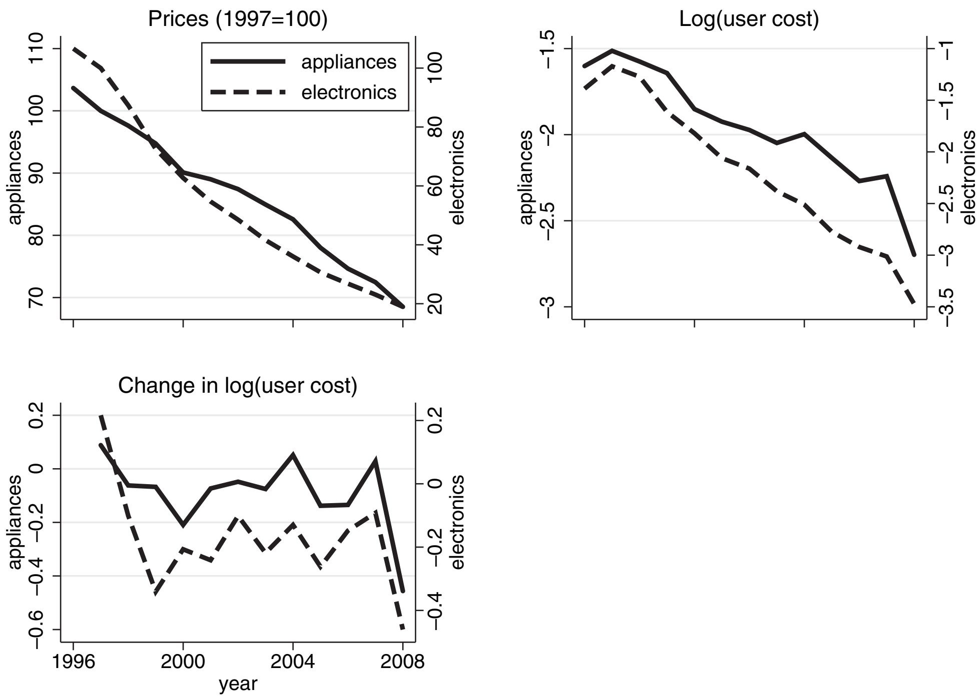

Figure 4. Prices and log user cost of durables over time

A model of durables demand

Consider a neoclassical model of durables demand (see, e.g., Deaton and Muellbauer, 1980, chapter 13). In such a model, the desired current *stock* of the durable, $S_{i,c,t}$, is given by:

$$S_{i,c,t} = (1-\delta)S_{i,c,t-1} + d_{i,c,t} \tag{3}$$

Inverting equation (3) gives durables purchases in each period as:

$$d_{i,c,t} = \delta S_{i,c,t-1} + \Delta S_{i,c,t} \tag{4}$$

where again δ is the rate of depreciation of the durable and $d_{i,c,t}$ is the *flow* of real purchases. In our empirical implementation, both $S_{i,c,t}$ and $d_{i,c,t}$ will be measured in hundreds of 1997 £. Equation (4) shows that there are two sources of demand for durables. The first is *replacement*; that is, replacing stock lost to depreciation, $\delta S_{i,c,t-1}$. The second source is *adjustment*, reflecting changes in the desired stock, $\Delta S_{i,c,t}$. In the neoclassical model, consumers accumulate their desired stock of durables instantaneously at the beginning of life and then future purchases follow from adjustment and replacement demands. Liquidity constraints and adjustment costs will slow down the initial accumulation of durables in early life so that *accumulation* demand may be relevant over a significant age range; see Fernandez-Villaverde and Krueger (2007). However, in later life, which is our focus, replacement and adjustment are the primary sources of demand.

We assume that utility, $u_{i,c,t}$, is inter-temporally additive and that within-period utility depends on consumption of a composite non-durable good, health status h, leisure, l, household demographics z and the flow of services from the durable good. As is standard, we assume the latter is proportional to the stock, $S_{i,c,t}$. Without loss of generality, it can then be measured in units of the stock (the factor of proportionality is subsumed in $u(.)$, the utility function). For convenience, we abstract from non-separabilities between non-durable goods and either leisure, health or durable services. However, we want to explicitly allow for non-separabilities between durables and leisure and health because we hypothesize that these may be critical to understanding patterns of durables demand, particularly around retirement and in later life. For example, time-saving home appliances are substitutes for non-market time while many electronic devices (such as TVs, home computers and audio equipment) are complementary to leisure. We also introduce here a taste shifter, θ, which we allow to vary across cohorts and with age: $\theta_{i,c,t} = g(C_{i,c}, A_{i,c,t})$. $C_{i,c}$, and $A_{i,c,t}$ are sets of dummy variables capturing, respective, birth-cohort and age-group membership. Thus, within-period utility from durable services and leisure is given by:

$$u_{i,c,t} = u(S_{i,c,t}, h_{i,c,t}, l_{i,c,t}, z_{i,c,t}, C_{i,c}, A_{i,c,t}) \tag{5}$$

The first-order conditions from the consumer's optimization problem relate the marginal utilities of leisure and the durable stock to the (appropriately discounted) marginal utility of wealth and the relevant price (the appropriately discounted user cost, v_t^*). The first-order conditions from the consumer's optimization problem can be solved to yield Frisch (or marginal utility constant) demands for consumption, leisure, and the durable *stock*. Under certainty, forward-looking, utility-maximizing consumers will endeavour to hold the marginal utility of wealth constant over time (and age). However, the marginal utility of wealth will vary across individuals, and in particular its average will differ across birth-cohorts because of technological progress and capital accumulation. We denote the marginal utility of wealth by λ. Given the potential non-separabilities between leisure and durables services and health status and durable services, the (conditional) Frisch demand for the durables stock will depend on the level of leisure and of health. The conditional Frisch demand for the durable stock is therefore:

$$S_{i,c,t} = f(h_{i,c,t}, l_{i,c,t}, z_{i,c,t}, v_t^*, \lambda_{i,c}, C_{i,c}, A_{i,c,t}). \tag{6}$$

Using this, we can relate the Frisch demand for a durable stock (6) back to the determinants of purchases. The *replacement* demand depends on the level of the (lagged) stock, and hence on affluence (that is, the marginal utility of wealth); the taste for durable services; the user-cost; the amount of leisure and health; and demographics. *Adjustment* demand depends on *changes* in desired stock and hence on *changes* in the user-cost, *changes* in the level of leisure and health; changes in demographics and *changes* in the agent's taste for durable services.

Choosing a simple functional form, we write this Frisch demand as:

$$S_{i,c,t} = \alpha_0 + \alpha_1 h_{i,c,t} + \alpha_2 l_{i,c,t} + \alpha_3 z_{i,c,t} + \alpha_4 \ln v_t^* + \alpha_5 \lambda_{i,c} + \theta_c C_{i,c} + \theta_a A_{i,c,t} \tag{7}$$

Equation (7) implies:

$$\Delta S_{i,c,t} = \alpha_1 \Delta h_{i,ct} + \alpha_2 \Delta l_{i,ct} + \alpha_3 \Delta z_{i,c,t} + \alpha_4 \Delta \ln v_t^* + \theta_a \tag{8}$$

Substituting both equations (7) and (8) into equation (4) gives:

$$
\begin{aligned}
d_{i,c,t} = & \delta S_{i,c,t-1} + \Delta S_{i,c,t} \\
= & \delta \alpha_0 \\
& + \alpha_1 \left[\delta h_{i,c,t-1} + \Delta h_{i,c,t} \right] \\
& + \alpha_2 \left[\delta l_{i,c,t-1} + \Delta l_{i,c,t} \right] \\
& + \alpha_3 \left[\delta z_{i,c,t-1} + \Delta z_{i,c,t} \right] \\
& + \quad \alpha_4 \left[\delta \ln v^*_{t-1} + \Delta \ln v^*_t \right] \\
& + \theta_a \left[\delta A_{i,c,t-1} + \Delta A_{i,c,t} \right] \\
& + \delta \theta_c C_{i,c} + \delta \alpha_5 \lambda_{i,c}
\end{aligned}
\tag{9}
$$

Note that there is a precise relationship between the coefficient on the user cost and its change (and similarly, there is a precise relationship between the coefficient on household size and on the change in household size.) In both cases, the ratio of the two must be the depreciation rate, δ. We use depreciation rates from the BEA Fixed Assets Accounts (BEA, 2004) to impose these restrictions (the same depreciation rates were used to construct the user costs in the previous section).[8] Practically this means using the depreciation rates to construct the terms in squared brackets above and then estimating the following model:

$$
\begin{aligned}
d_{i,c,t} = & \alpha^*_0 + \alpha_1 [\widetilde{h_{i,c,t}}] + \alpha_2 [\widetilde{l_{i,c,t}}] + \alpha_3 [\widetilde{z_{i,c,t}}] + \alpha_4 [\widetilde{\ln v^*_t}] \\
& + \theta_a [\widetilde{A_{i,c,t}}] + \theta_c C^*_{i,c} + \alpha_5 \lambda^*_{i,c}
\end{aligned}
\tag{10}
$$

(where $\lambda^*_{i,c} = \delta \lambda^*_{i,c}, C^*_c = \delta C_{i,c}$ and $\widetilde{x}_t = \delta x_t + \Delta x_t$ for $x = h, l, z, \ln v^*, A$, and $\Delta A = 0.1$ because age is measured in decades).

Note from equation (7) that the coefficients $\alpha_1 \ldots \alpha_4$ are derivatives of the demand for the stock (equal to the *flow* of services). Equation (9) shows that derivatives of the flow of purchases (which is distinct from the flow of services) are obtained by adjusting the coefficients $\alpha_1 \ldots \alpha_4$ for the depreciation rate δ. Recall that both the stock and the flow of purchases are measured in hundreds of pounds sterling at 1997 prices (1997 £). Thus, for example, α_4 gives the increase in the desired stock, $S_{i,c,t}$, in hundreds of 1997 £, with an increase in the current logarithm of the user cost, $\ln v^*_t$, holding all else constant. The product $\alpha_4 \delta$ gives the increase in the flow of purchases, $d_{i,c,t}$, in hundreds of 1997 £, with an increase in the current logarithm of the user cost, $\ln v^*_t$, holding all else constant, including the logarithm of the lagged user cost, $\ln v^*_{t-1}$. We expect α_4 to be *negative*, as the own-price derivative of the Frisch demand should be negative.

Relating these observations back to our empirical specification (1), we note that:

(i) the age effects A capture the evolution of the household's taste for durable services as the household head ages.

(ii) The cohort effects C capture cohort-specific tastes. Households with members from older cohorts might have different preferences. Such taste differences could result from growing up in a less technologically advanced world. Our hypothesis would be that older cohorts are more detached from modern product innovations and thus we would expect larger expenditures on durables for younger cohorts. However, due to our use of

[8] Recall that the assumed depreciation rates are 0.165 for appliances and 0.183 for electronics.

Frisch demands, cohort effects also capture cross-cohort differences in the (average) marginal utility of wealth. Due to the considerable increase in wealth among younger cohorts, we expect this to reinforce the effect of cohort tastes.

(iii) There are two ways in which we might deal with the unobserved marginal utility of wealth. First, as just noted, cohort effects will capture the cohort mean of this variable. The remaining individual deviation from cohort mean is by construction uncorrelated with age variables, and so does not matter for the estimation of age profiles. Alternatively, we can exploit the fact that we have true panel data and estimate our model in first differences (eliminating both the marginal utility of money and the cohort-specific taste effect, as well as any other time-invariant effects). Below we report estimates based on both of these strategies.

(iv) The time effects $\phi(t)$ capture the depreciated (log) user-cost and *changes* in the (log) user-cost. Thus, we model time effects as simple functions of user costs and changes in user costs through the term $\left[\widetilde{\ln v_t^*}\right]$ and make the less restrictive assumption that there are no other time factors affecting the demand for the durables considered. Note that, as the linear trend in user costs (and user cost changes) will be collinear with age and cohort, the effects of user costs are estimated from the year-to-year departures of user costs (and user cost changes) from a linear trend. Figure 4, above, indicates that these may be modest but, as we will document below, they turn out to be sufficient to deliver precise estimates of user cost effects.

In our implementation of equation (10), we specify age as a fourth-order polynomial. Age is normalized to zero at age 60, so that at age 60 derivatives depend only on the first-order term. Desired stocks and purchased flows are measured in hundreds of 1997 £ while age is measured in decades. Thus, the coefficient on the first-order age term, multiplied by $100/10 = 10$, gives the effect of an additional year of age on the desired stock in 1997 £. Multiplying this amount by the good-specific depreciation rate gives the effect on the flow of purchases in 1997 £.

Frictions

Above we have assumed a neoclassical, or frictionless adjustment, model of durables. The literature on durables has emphasized the importance of adjustment costs and irreversibility; see, for example, Attanasio (2000), Bar-Ilan and Blinder (1992) and Grossman and Laroque (1990). For the goods we model, we believe that adjustment costs are small: buying and installing a new television is straightforward. However, significant resale discounts suggest an important degree of irreversibility. How might this affect life-cycle patterns of durables demand? A formal analysis of irreversibility is provided in Browning and Crossley (2009). Irreversibility adds an additional constraint to the household's problem $\left(d_{i,c,t} \geqslant 0\right)$, and the associated multiplier appears in the first-order conditions whenever this constraint binds. The key point is that the expectation of the next period value of this multiplier affects the current marginal rate of substitution between durable and non-durable consumption (see equation 2.13 in Browning and Crossley, 2009). In the frictionless model, this marginal rate of substitution is just equal to the user cost (if the price of non-durable consumption is normalized to one). If there is any state of the world in which the household might have 'too much' durable stock in the next period, then the expectation of the next period multiplier on the irreversibility constraint is positive. This has the same effect as an increase in user cost: the marginal utility of durable consumption must rise relative to the marginal utility of non-durable consumption (intuitively, if 'excess' stock cannot be disposed of at the end of the current period, then the cost of non-durable consumption in the current period is higher). In turn this means that households that face the possibility of excess stock in the next period (in any state of the world) will hold lower stocks of the durable than would be suggested by a model with reversibility. Finally, unless durable stocks can be bequeathed, and households value a bequest of a durable equally to a cash bequest of the replacement cost of the stock, the irreversibility constraint will bind at the end of life. This suggests that the expected value of the irreversibility multiplier should increase as the end of life approaches, depressing the desired stock and generating an age effect in durables demand. These age effects, which may be highly nonlinear, will be picked up by flexibly estimated age profiles.[9]

IV. Results

Our main results are in Table 1 (for appliances) and Table 2 (for electronics). In each case, the dependent variable is quantities purchased (or real expenditures) measured in hundreds of pounds sterling at 1997 prices. However, as noted above, the coefficients here (with the exception of the constant) should be interpreted as effects on desired stocks (that is, service flows) measured in hundreds of pounds sterling at 1997 prices. Effects on desired purchases are obtained by multiplying by the good-specific depreciation rate.

Each column represents a richer specification of the purchases equation. Specification (1), shown in column (1), contains only a fourth-order polynomial in age. This specification corresponds to the cross-sectional age profiles reported in Figure 1. Again, for both goods these cross-sectional age profiles are steeply declining from age 40 onwards and jointly statistically significantly different from zero, as shown by the F-test at the bottom of column (1) in Tables 1 and 2.

In specification (2), we allow for non-zero cohort effects (modelled as a quadratic in the year of birth). For both durables, we find substantial, positive and statistically significant cohort effects that are attributable to the higher lifetime wealth (and hence lower marginal utility of wealth) of younger cohorts and potentially to a stronger preference for durables in younger cohorts, especially for consumer electronics. The introduction of cohort effects leads to insignificant age profiles for appliances (see F test results at the bottom of Tables 1 and 2), and changes the sign of the age profiles for electronics, so that demand for quantities of electronics increases (rather than decreases) with age, once cohort patterns are accounted for.

This can also be seen in the lower panels of Figure 5 for appliances and Figure 6 for electronics. The straight lines, labelled as specification (1), show the strongly negative age profiles when cohort-specific patterns are not taken into account. The dashed lines, depicting the estimated profiles from specification (2) show the resulting change in the age

[9]The expected life of household appliances is about 10 years while consumer electronics depreciate slightly faster and have a slightly shorter expected life (Bureau of Economic Analysis, 2004; see also Bils and Klenow, 1998). This bounds the range of ages over which these end-of-life effects are likely to be operative.

TABLE 1

Estimation results, appliances

Dependent variable: household appliances, quantities purchased (in 1997 prices)†				
	cross-section regressions			*Panel FE*
	(1)	*(2)*	*(3)*	*(4)*
Age	−0.981	0.055	0.124	0.117
	(15.32)**	(0.35)	(0.70)	(0.54)
Age^2	−0.031	−0.018	−0.022	−0.200
	(0.52)	(0.25)	(0.32)	(1.69)
Age^3	0.055	−0.013	−0.021	−0.044
	(1.42)	(0.31)	(0.49)	(0.90)
Age^4	−0.015	0.003	0.006	0.030
	(1.08)	(0.21)	(0.41)	(1.46)
Year birth		0.879	0.869	
		(8.33)**	(7.11)**	
Year birth^2		0.039	0.043	
		(0.85)	(0.92)	
$\ln(uc_{appl})$			0.010	0.021
			(0.15)	(0.31)
ln(hhsize)			0.431	0.001
			(7.54)**	(0.02)
Kids 0–2			−0.078	0.145
			(0.80)	(1.47)
Kids 3–4			0.074	0.181
			(0.96)	(2.20)*
Kids 5–11			−0.103	−0.100
			(2.02)*	(1.72)
Kids 12–15			−0.057	−0.037
			(1.23)	(0.72)
Kids 16–18			−0.032	−0.034
			(0.72)	(0.73)
Retired			0.003	0.024
			(0.07)	(0.63)
Mean no. of health problems			0.014	0.014
			(1.67)	(1.76)
Constant	0.768	0.630	0.583	0.728
	(64.53)**	(29.36)**	(20.16)**	(21.96)**
Observations	60,697	60,697	60,696	60,696
No. households				10,011
F-test Age	201.33	0.08	0.15	0.89
P-value	<0.01	0.99	0.97	0.47

Notes: Robust t statistics in parentheses; * significant at 5%; ** significant at 1%.
†: quantities are divided by 100 to make the results more readable. Age and cohort are measured in decades and normalized to zero at age 60 and 1940s cohort. Reported coefficients are estimates for the coefficients in the stocks equation (8) from section 'A model of durables demand'.

TABLE 2

Estimation results, consumer electronics

Dependent variable: consumer electronics, quantities purchased (in 1997 prices)†				
	cross-section regressions			*Panel FE*
	(1)	*(2)*	*(3)*	*(4)*
Age	−6.480	19.704	13.907	18.337
	(20.81)**	(25.25)**	(14.09)**	(14.93)**
Age^2	−0.653	−2.282	−2.497	−2.779
	(2.28)*	(6.85)**	(7.51)**	(4.88)**
Age^3	0.142	−1.698	−1.378	−1.891
	(0.77)	(8.78)**	(7.02)**	(7.70)**
Age^4	0.071	0.612	0.536	0.653
	(1.06)	(8.88)**	(7.73)**	(6.45)**
Year birth		21.686	15.531	
		(38.07)**	(19.03)**	
Year birth^2		2.658	2.561	
		(10.70)**	(10.32)**	
$\ln(uc_{elec})$			−2.768	−2.568
			(9.15)**	(8.46)**
ln(hhsize)			3.273	0.947
			(11.74)**	(2.91)**
Kids 0–2			−1.268	−0.764
			(2.46)*	(1.48)
Kids 3–4			−1.296	−0.858
			(2.98)**	(1.88)
Kids 5–11			−0.282	0.057
			(0.95)	(0.18)
Kids 12–15			0.013	0.043
			(0.05)	(0.16)
Kids 16–18			0.033	0.179
			(0.14)	(0.73)
Retired			0.348	0.410
			(1.80)	(2.06)*
Mean no. of health problems			0.079	0.090
			(1.92)	(2.12)*
Constant	4.355	0.874	−0.318	1.587
	(69.20)**	(9.53)**	(2.39)*	(9.18)**
Observations	60,700	60,700	60,699	60,699
No. households				10,012
F-test Age	431.11	191.25	53.21	57.58
P-value	<0.01	<0.01	<0.01	<0.01

Notes: Robust t statistics in parentheses; * significant at 5%; ** significant at 1%.
†: quantities are divided by 100 to make the results more readable. Age and cohort are measured in decades and normalized to zero at age 60 and 1940s cohort. Reported coefficients are estimates for the coefficients in the stocks equation (8) from section ‘A model of durables demand’.

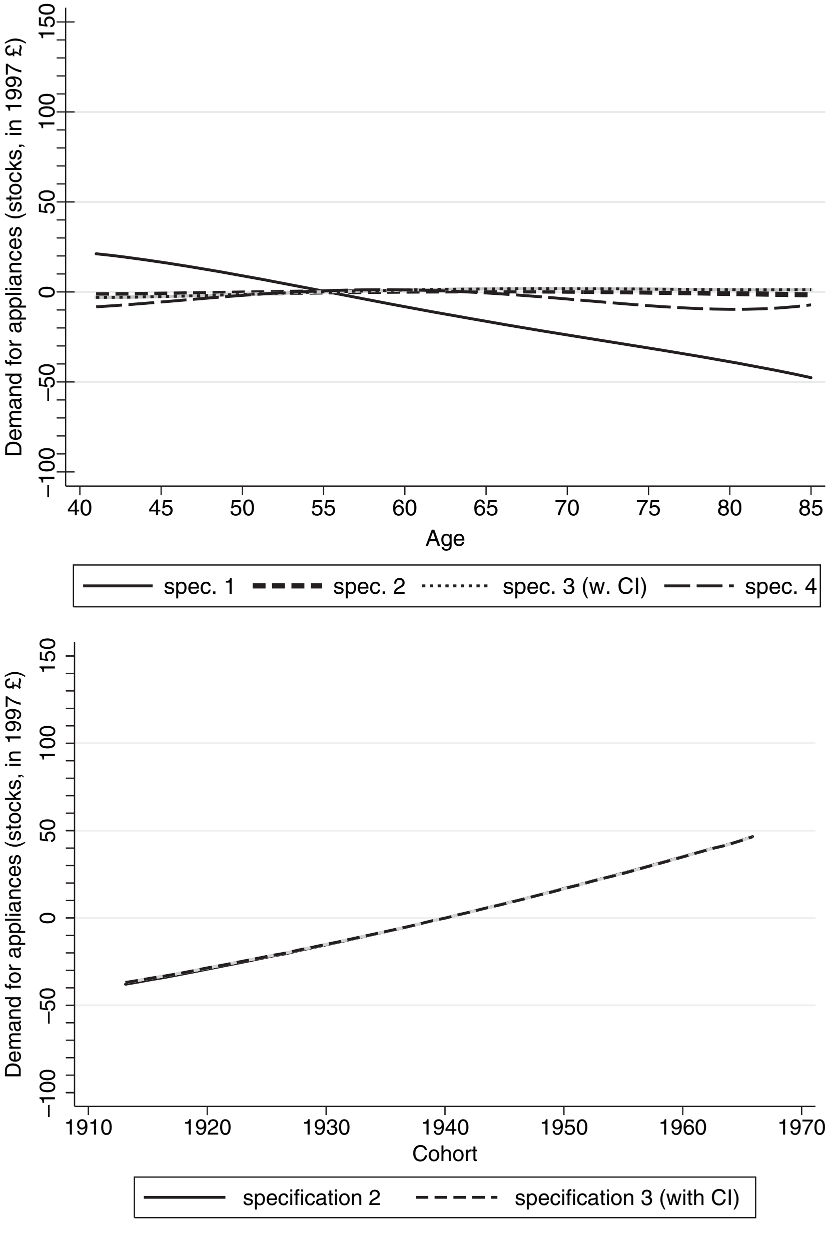

Figure 5. Estimated age and cohort profiles, demand for appliances
Notes: Age and cohort effects are normalised to zero at age 60 and for the 1940s cohort. They are based on the estimated coefficients which are estimates for the coefficients in the stocks equation (8) from section 'A model of durables demand'.

profiles. For appliances, these profiles are not statistically significantly different from zero. For electronics, we see increasing demand across all ages that slows down slightly beyond age 65. In Figures 5 and 6, we have adjusted the estimated coefficients by the depreciation rates so that these are the age and cohort profiles of real expenditures (rather than stocks). Note that the scale in Figure 5 is 10 times larger than the scale in Figure 6.

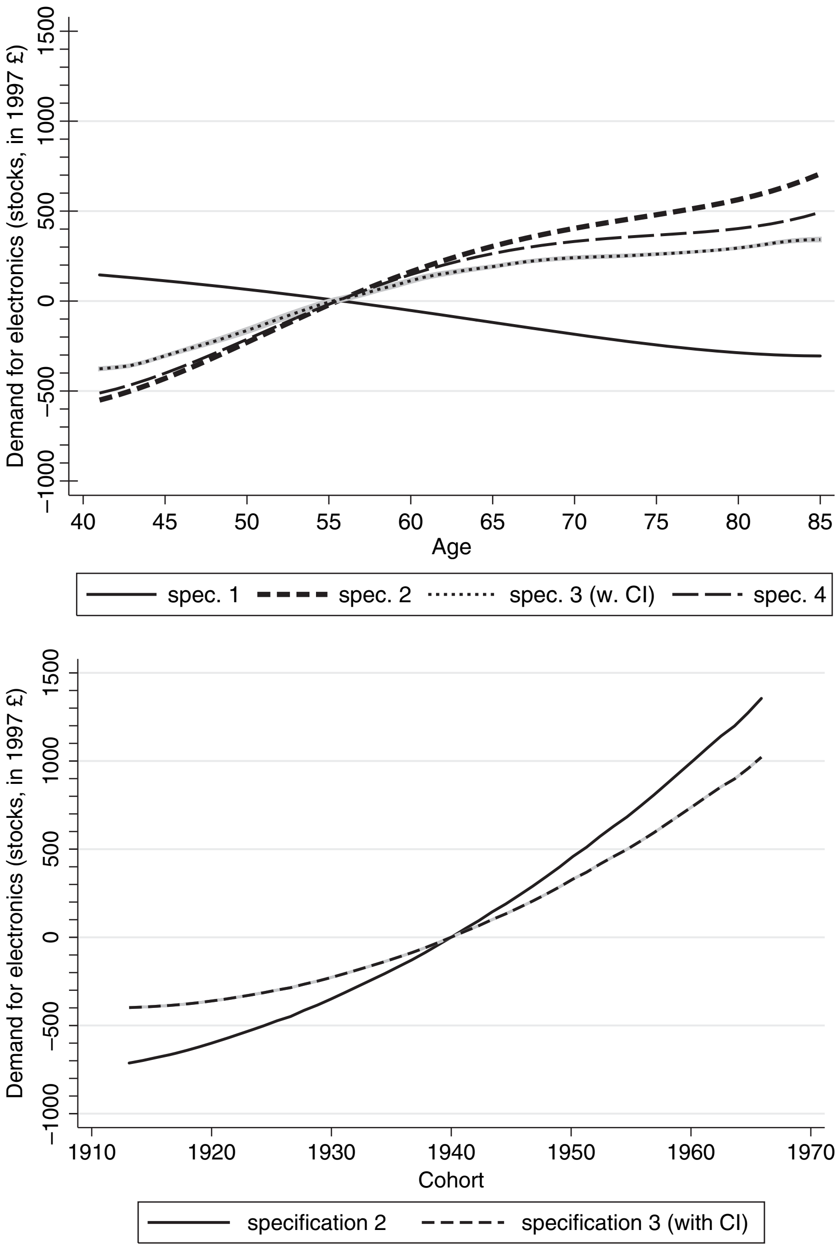

Figure 6. Estimated age and cohort profiles, demand for electronics
Notes: Age and cohort effects are normalized to zero at age 60 and for the 1940s cohort. They are based on the estimated coefficients which are estimates for the coefficients in the stocks equation (8) from section 'A model of durables demand'.

In specifications (3) and (4) (again Table 1 for appliances and Table 2 for consumer electronics), we present estimates of our complete specification.[10] This includes, in addition

[10] We lost one observation when moving from specification (2)–(3) because of missing information on household composition and work status.

to age and cohort effects, period effects modelled as user costs; household size and composition variables; and controls for the labour supply and health of the household, which are intended to capture non-separabilities between durables services and leisure or health. Specification (4) differs from (3) in that we allow for household fixed effects. The cohort controls in specification (3) (and also specification (2)) capture differences in the average marginal utility of wealth between cohorts and cohort-specific taste shifters. There will be household-specific deviations from cohort mean in both the marginal utility of wealth and tastes for durables. However, to the extent that these deviations are time invariant, they are, by construction, orthogonal to age (because, conditional on birth cohort, age varies only with time). Thus they should not affect our estimates of the age profile. However, this is only strictly true in a balanced panel (and our panel is not balanced). As the BHPS is a panel, we can allow for household variation in the marginal utility of wealth and in tastes for durables by introducing household-level fixed effects. We do this in specification (4). Naturally, the introduction of household fixed effects takes out time-invariant variables, notably the birth-cohort variables.

The literature suggests that household demographics, especially household size and composition, strongly affect the demand for durables (see, e.g., Fernandez-Villaverde and Krueger, 2005, 2007). Larger households may have greater needs for private goods. For many durables there is no strict rivalry in their consumption, so that they are public goods within the household. This may mean that needs do not rise proportionally with household size but it also implies that the effective 'price' of these goods is lower for larger households. This will increase the demand for stocks and subsequently purchases. Appliances are likely to be more public than consumer electronics. Specifications (3) and (4) capture household size and composition through the log of household size and dummies for the presence of children of different age groups (0–2, 3–4, 5–11, 12–15, 16–18).

Household labour supply is captured by a variable indicating whether any household members report themselves as retired. If consumer electronics are complements to leisure, we would expect an increased consumption in retirement. Figure 7 shows self-reported retirement status by age in the upper panel and retirement entry age in the lower panel.[11] The distribution of retirement entry age shows two large spikes, at 60 and 65 years, the state pension ages for females and males during the sample period. This suggests that potential adjustments in durables demand due to changes in leisure with retirement would also bunch around these ages.

Deteriorating health status may shift time use towards (sedentary) activities at home, and increase the demand for labour-saving devices. Our measure of the health status of household members reflects the average number of health conditions present in the household. [12] The BHPS contains a set of question asking about thirteen health problems or disabilities such as problems with back or limbs, sight, hearing, skin conditions and allergies, chest and breathing, heart and blood pressure, stomach or indigestion, diabetes, anxiety or depression, alcohol or drugs, epilepsy, migraine and other conditions. We sum

[11] We alternatively defined a measure of inactivity rather than retirement, defining 'retirement' as the self-reported status of 'not working'. The distributions across age look very similar. The measures create different levels in retirement frequencies at a particular age, but the shape of the transition patterns is almost identical.

[12] We find qualitatively similar effects using limitations to activities of daily living (ADLs) as an alternative health measure. However, these are only recorded for respondents aged 65 and older.

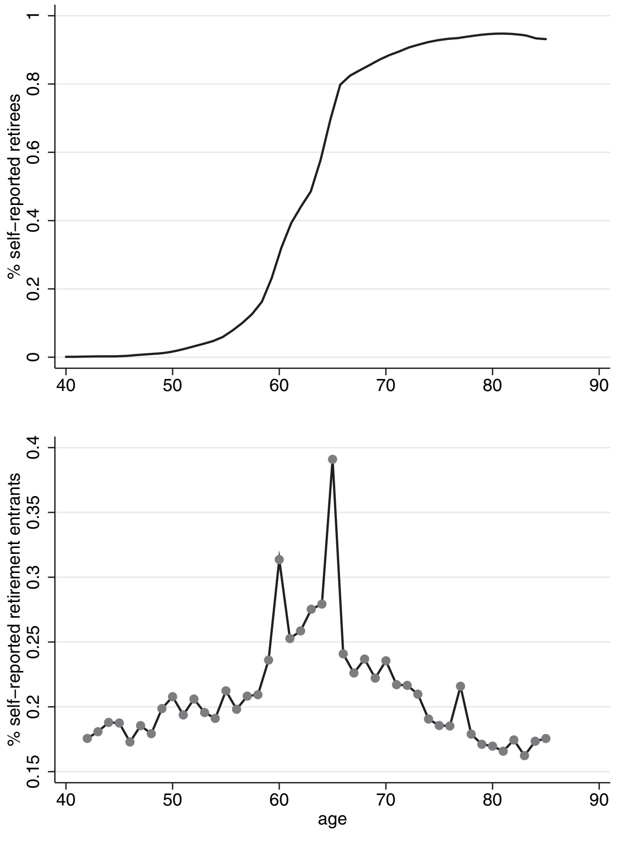

Figure 7. Retirement status and retirement entry by age

these up for each household member and compute the average number of conditions present in the household. Figure 8 shows the increasing prevalence of health problems by the age of the household head. Our measure is highly positively correlated with other common health measures such as limitations in activities of daily living (ADL) and captures mobility limitations and disability (Strauss *et al.*, 1993; Sacker *et al.*, 2003). Note that higher values of this variable indicate worse health.

An examination of the estimates of specification (3) in Tables 1 and 2, and the corresponding plots in the bottom panels of Figures 5 and 6, reveal that the addition of demographic, health, labour supply and user costs variables has little effect on our estimated cohort effects. For appliances, the estimated birth-cohort profile from specification (3) (the dotted line) is almost indistinguishable from that coming from specification (2) (the solid line). It is a bit easier to distinguish the cohort profiles for consumer electronics, in Figure 6, but they still have very similar shapes. The cohort effects for consumer electronics are much larger than those for appliances. This could reflect the fact that the former have large income elasticities (are more luxurious) so that the same cohort difference in wealth (or the marginal utility of wealth) leads to larger differences in demand. Another explanation would be larger cross-cohort differences in tastes for consumer electronics than tastes for appliances.

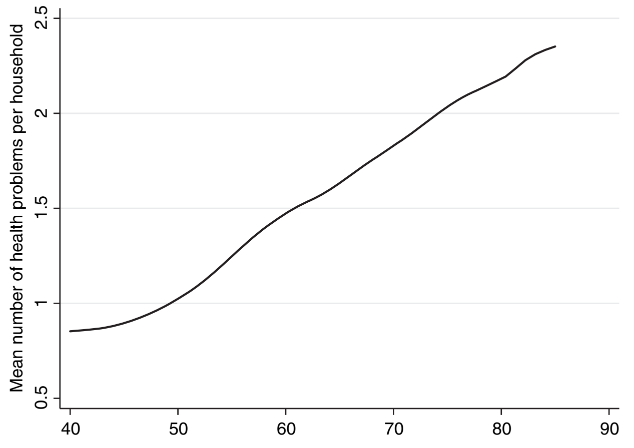

Figure 8. Health status by age

Turning to the age profiles, Tables 1 and 2 and Figures 5 and 6 show that they are very little affected by the inclusion of user costs; household size and composition variables; controls for the labour supply and health of the household; and household fixed effects. Both specifications (3) and (4) give an age profile for appliances demand that is very flat (see the top panel of Figure 5). For consumer electronics, controlling for household size and composition, labour supply, health and user costs (specification (3)) reduces the positive slope of the age profiles somewhat, but allowing for household fixed effects moderates this effect (see the top panel of Figure 6). Recall that age is normalized to age 60, so that at age 60 derivatives depend only on the first-order term. In our preferred specification, (4), with household fixed effects, this is 18.34. As explained in Section 3, this is the effect on desired stock; to get the effect on purchase flows we multiply by the depreciation rate which is 0.183. Thus, our preference specification suggests that at age 60, the desired stock of consumer electronics is growing each year by the amount that could be purchased with $18.34 \times 100/10 \approx 183$ 1997 £; the corresponding increase in annual purchases is approximately $183 \times 0.183 = 33$ pounds (at 1997 prices) each year.

To summarize, allowing for cohort effects (in specification 2) dramatically changes the estimated age profile of durables demands. This is because of the strong cohort effects, with later cohorts (who are younger in our data) having greater demand for both appliances and electronics. This certainly reflects their higher wealth (lower marginal utility of wealth), and may also reflect cohort average differences in tastes. In contrast, the inclusion of user costs, household size and composition variables, controls for the labour supply and health of the household, and household fixed effects has very little effect on the estimated age profiles. Controlling for user costs and for household size, composition, labour supply and health also had very little effect on the estimated cohort effects.

The direct effects of these variables on the demand for appliances and for consumer electronics are also of interest. We find little effect of user costs on the demand for appliances, and modest but statistically significant effects of user cost on the demand for electronics. The latter have the expected negative sign. As we do not observe the stock, we cannot calculate elasticities of the desired stock with respect to user cost. We can, however, calculate elasticities of purchase rates with respect to a change in the current user cost (holding lagged user costs constant). For example, in Specification 3, the confidence interval for the user cost coefficient in the appliances equation is [−0.12, +0.14]. At the mean rate of purchases, this implies that the absolute value of the elasticity is less than 0.2 (range [−0.17, 0.2], where we would expect it to be negative). In contrast, the confidence interval for the user cost coefficient in electronics equation implies a range of elasticities of −0.87 to −0.57 (again using the estimated coefficient from specification 3 and the mean rate of purchases.) Thus, we conclude that electronics are moderately user-cost elastic while appliances are not.

While we do find the expected positive significant effect of household size for both durables, we do not find larger effects for appliances than for electronics. We also do not find much evidence of durable purchases that would be specific to the age composition of children in the household. Our results are in contrast to the much larger household composition effects found by Fernandez-Villaverde and Krueger (2007) who concentrate on large durables such as cars and housing. They also find that around half of the age profile in spending on larger durables can be explained by dynamics in the household composition over the life-cycle, while as noted above, our estimated age profiles for appliances and consumer electronics are largely unaffected by accounting for changes in household size and composition.[13]

We find no evidence that retirement affects the demand for appliances. We find a small positive effect of retirement on the demand for consumer electronics that becomes statistically significant when we include household fixed effects (in specification (4)). Retirement is measured by a [0,1] dummy and the desired stock is measured in hundreds of 1997 £. Thus, the magnitude of the effect is to increase the desired stock of consumer electronics by the quantity that could be purchased for $0.41 \times 100 = 41$ £ sterling (about 60 US dollars) in 1997. Multiplying by the depreciation rate for consumer electronics gives the effect on the flow of purchases: $41 \times 0.183 = 7.5$ 1997 £ per year.[14]

Health deteriorations, measured as the accumulation of a set of health conditions, are associated with a higher demand for electronics. Again the effect is significant at conventional levels when we allow for household fixed effects. Economically the effect is more modest than the retirement effect. The estimates imply that one additional health condition in the household would raise the desired stock of consumer electronics by the quantity that could be purchased for nine £sterling (about 14 US dollars) in 1997. We do not see evidence, in any specification, of an impact of health conditions on the demand for appliances.

V. Discussion

The contribution of this paper is partly methodological. In disentangling age, cohort and period effects, one should take care to apply solutions appropriate to the question at hand. In

[13] We also investigated the effect of downsizing in housing or moving to a different location, e.g., to be closer to children or closer to shops and amenities. Though much lower than in the US, Banks *et al.* (2010) find some evidence of downsizing in housing in the UK. This might be accompanied by increased expenditures as some durables may not fit into the new home or households may have postponed adjusting their durable stock prior to moving. Augmenting our preferred specification with a mover dummy revealed that moving house is strongly and statistically significantly associated with a higher demand for both durables, although the effect appears stronger for appliances. Full results are available from the authors.

[14] Similar results (available from the authors) are obtained if we condition on the retirement status of the head of the household rather than on the existence of retired household members.

modelling the life-cycle profiles of demand for specific consumption goods (or equivalent, of the composition of spending), a key period effect may be changes in relative prices or user costs. In our analysis of the life-cycle pattern of demands for home appliances and consumer electronics, we found strong evidence of a time trend in the user costs for both appliances and electronics. The presence of a trend in user costs suggested that restricting period effects to be orthogonal to a time trend was not appropriate in this application and motivated our use of the alternative approach of explicitly modelling period effects. In this application, in which period effects are accounted for by user costs and changes in user costs, this approach appeared to work well. We find modest but statistically significant reductions in the demand for electronics with increases in the user cost. The demand for home appliance services appears to be price inelastic.

We find a significant effect of household size on the demand for both categories of durables. We find no impact of leisure or health status on the demand for appliances, but these variables have significant effects on the demand for consumer electronics. While demographics (and in the case of electronics, user costs, leisure and health status) are significant determinants of demand, they have little material effect on the age profile of demands. Once we condition out cohort effects, the age profiles are quite robust to other changes of specification.

Our estimates suggest that complementarity between consumer electronics and leisure increases the demand for consumer electronics after retirement. We find that poor health has no effect on the demand for appliances but increases demand for consumer electronics. Consumer electronics appear to be substitutes for good health status. Ideally these tests would be with respect to *anticipated* changes in health and leisure, but we have no plausible instruments. With respect to health changes, it seems probable that a negative health shock decreases the marginal utility of wealth (leading to higher expenditure). Thus, if part of the reductions in health is unanticipated, we are likely overestimating the degree of substitutability between consumer electronics and health.

The dependence of (marginal) utility on health is very important for a range of policy questions (e.g., the optimal provision of health insurance) but there is very little evidence on this point (Finkelstein *et al.*, 2009). A number of authors have pointed out that, to answer policy questions such as the optimal provision of health insurance, we need to know the overall degree of substitutability or complementarity between consumption and health. This is true, but it does not follow that we should focus on consumption aggregates. As many of the same authors point out, the overall substitutability or complementarity between health and consumption is not obvious exactly because some components of consumption are likely to be substitutes for good health (consumer electronics, medical aids) while others are likely complements (travel, skis). This implies that the overall degree of substitutability or complementarity between health and consumption is not a structural parameter, but will depend on prices and other factors that shift the pattern of demands. We need to study how health affects demand patterns and the work reported here is one step in that direction. The effects of health on demand are an important topic for further investigation.

The primary motivation for our analysis was to investigate the presence of pure age effects in the demand for medium-sized durables. In cross-section, real expenditures on appliances and consumer electronics decline as households age. However, when we model demands more carefully, we find that the downward-sloping age-specific profile of appliances demand is entirely explained by cohort effects. Once we condition on these, there is no age effect. For consumer electronics, we find even larger cohort effects and conditioning on birth cohort reverses the cross-sectional pattern so that demand for electronics *rises* with age.

These results are very plausible. The larger cohort effects in the demand for consumer electronics could reflect the fact that these goods are more luxurious (and so more sensitive to differences in lifetime wealth) or could reflect larger cross-cohort differences in tastes for consumer electronics. Our discrete and somewhat crude measures of leisure and health suggest that both are important determinants of the demand for consumer electronics. The rising demand for electronics with age might in part reflect gradual increases in leisure that are not captured by our retirement variables, and a gradual reorientation of leisure to more sedentary activities. The latter may in turn be associated with gradual reductions in health and physical capacity that are not captured by our crude measure.

Our analysis has gone beyond most of the life-cycle consumption literature by considering the life-cycle pattern of demand for multiple goods, and allowing for preference shifts with cohort and age. Of course, there may be further and important differences at even finer levels of disaggregation. For example, there may be differences across cohorts in the extent to which individuals are comfortable with computers, but no such differences for televisions. Similarly, while we have gone beyond the literature in our modelling of age, time and cohort effects, there may be subtler interactions between age and time effects that we have not modelled. Computers, for example, have become simpler to use over time and this may have altered the age profiles of demands for them. As is always the case, there is scope for future work.

This rising demand for some durables with age documented in this study is (yet another) explanation for the often documented decline in non-durable consumption spending in later life: preferences simply shift towards durables (particularly consumer electronics) with age. The corollary of this explanation is that if we attribute the decline in non-durable consumption to impatience (as in, e.g., Gourinchas and Parker, 2002), we are assuming that all demands decline with age and hence will underestimate savings required for retirement.

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